Wind Effect Measurements on a Full Scale Tall Building and a TV Tower

AUTHOR(S):

ISHIZAKI, Hatsuo; MUROTA, Tatsuo

CITATION:

ISHIZAKI, Hatsuo ...[et al]. Wind Effect Measurements on a Full Scale Tall Building and a TV Tower. Bulletin of the Disaster Prevention Research Institute 1970, 19(4): 37-44

ISSUE DATE:

1970-03

URL:

http://hdl.handle.net/2433/124781

Bull. Disas. Prev. Res. Inst., Kyoto Univ., Vol. 19, Part 4, No. 166, March 1970 37

Wind Effect Measurements on a Full Scale Tall Building and a TV Tower

By Hatsuo ISHIZAKI and Tatsuo MUROTA

(Manuscript received January 19, 1970)

Abstract

The significance of wind effect measurements on full scale buildings and structures is stated and an experiment to measure wind effects is outlined.

The measurements are being made on a 22-story hotel building and a TV tower 160m high in Osaka City. Wind structures over the city, wind loadings and responses of the building and tower are contemplated to be measured. Some results on the response of the tower in a typhoon wind are shown.

1. Introduction

With the recent increase of tall buildings, towers or masts following the trend of the refinement of structural design techniques, the need for more detailed estimations of wind effects on buildings and structures is becoming more important.

In order to estimate the wind load, it is necessary to know the wind structure and its variation around buildings or structures. The former is concerned with the occurrence probability of extreme winds and the turbulent structure of wind in the atmospheric boundary layer. The latter is concerned with the spatial and hourly wind pressure distribution on buildings and structures and their corresponding oscillatory responses.

Several approaches have been made to these problems and wind structures have become clearer for engineering purposes, but knowledge of the wind pressure distribution on buildings and structures and the corresponding oscillatory responses is not yet sufficient.

For present practical needs, these problems are investigated by model tests in boundary layer wind tunnels simulating the turbulent structures of wind. But these results have not been compared in detail with those of full scale models due to the want of data about wind effects on actual buildings or structures.

Full scale data are also necessary to provide knowledge of the turbulent structure of wind in the urban boundary layer up to a height comparable to tall buildings. In this region the turbulent structure of wind is considered to be very complicated and a few studies have been made. Two examples will be shown concerning the complicated nature of wind in the city boundary layer after the damage investigation reports of the Muroto Typhoon, which attacked the city of Osaka in 1934 with an intense wind force of 60m/sec.

Fig. 1 illustrates the damage to the window glass of 6- to 11-story buildings which were the highest buildings in Osaka at the time. The damage shows that

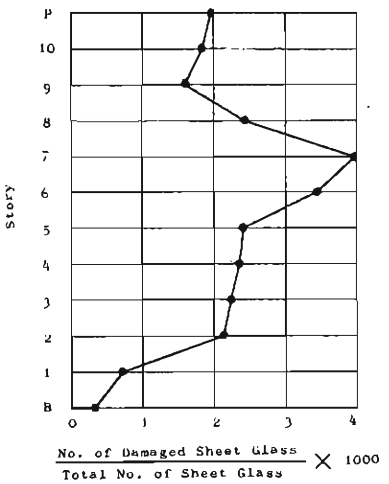


Fig. 1 Relation between the damage to window glass and the story in which the glass is set. (obtained from the statistics for 20 buildings of 6 to 11 storys)

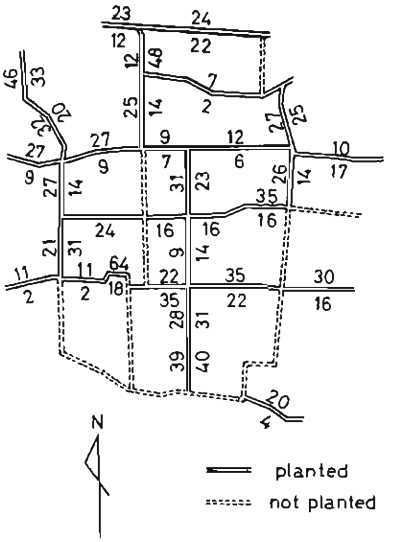


Fig. 2 Damage to street trees on each side of streets. Numerals in this figure are the percentages of uprooted trees.

the change in the wind structure is not uniform with height. Fig. 2 illustrates the distribution of uprooted street trees, which shows the complex nature of the city wind in plane.

One of the first attempts to measure the wind effects on a tall building was carried out on the Empire State Building by Rathbun[2]. The pressure distribution of the wind over the surface of the building was measured by U-tube manometers and at the same time the movement of the top of the building and the stresses in some of the members of the frame were observed by collimeters and extensometers. The manometers used in making these measurements were inadequate to deal with the complexity of the problems to be solved, but it was found that the building vibrates about the deflected position in wind.

Recent attempts to measure the wind loading on a full scale were started at a 15-story office building, State House, London, in 1961, by Newberry[3] with equipment developed by the Building Research Station for the detailed study of wind pressures. Indicating some of the problems of full scale measurements, it was concluded that the most difficult, yet most important problem is the establishment of a suitable reference pressure against which the external pressure can be measured.

In the International Research Seminar[4] on Wind Effects on Buildings and Structures held at Ottawa in 1967, some papers reported the results of wind pressure measurements on full scale buildings in the U.K., Canada, U.S.A. and the Netherlands. However, data is still too limited for a full understanding of wind effects, and further full scale measurements are essential to further development.

In Japan similar attempts are planned for several high-rise buildings in Tokyo, Kyoto[5], Osaka and Kobe and some of them are being put into effect. In Osaka measurements are being carried out on a 22-story hotel building and a 160m TV tower. The instrumentation was completed in 1968. This paper will describe the outline of the measurements.

2. Purpose of the Measurements

The measurements contemplated are to obtain knowledge about the following : —

(1) the mean wind profile over the city up to a height of 120m.
(2) the turbulent structures of city wind and its variation with height.
(3) the nature of wind pressures on buildings and towers.
(4) the nature of the responses of buildings and towers in wind.

3. Description of Site, Building and Tower

The measurements are being carried out at Osaka Tower and the Plaza Hotel (Photos 1, 2), which are in close proximity and located in Oyodo-ku, Osaka as shown in Fig. 3. The site is near the Yodo River and Osaka Station, which is on the northern edge of the most built-up area in Osaka. Buildings are crowded around the site but most of them do not exceed 30m in height, as shown in Photo. 1.

Fig. 4 is a site plan near the building. Osaka Tower, the Plaza Hotel and the ABC Center Building are in close proximity.

Osaka Tower is a steel trussed TV tower 160m high, having squares sections of 14m × 14m up to 100m and 4m × 4m up to 140m. It has two look-out platforms cladded with windows at heights of 90 and 95m.

The hotel building is 22-storied and has rectangular plans of 35 × 114m up to the fifth floor and 15m × 88m up to the 22nd floor. The top of the roof parapet

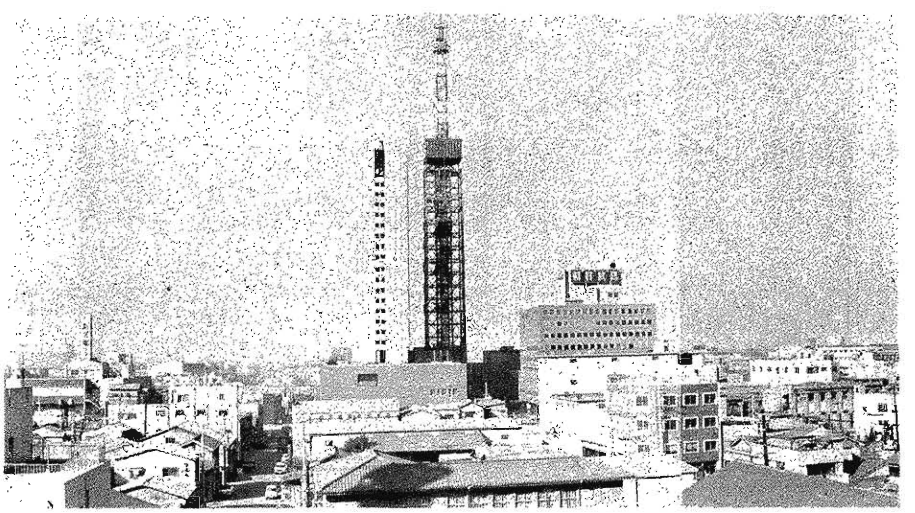


Photo. 1 East view of the Plaza Hotel and Osaka Tower.

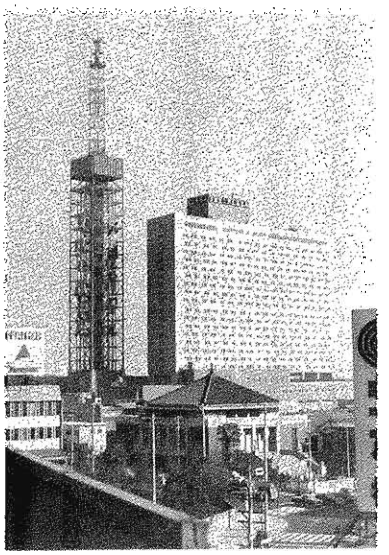


Photo. 2 South-west view of the Plaza Hotel and Osaka Tower.

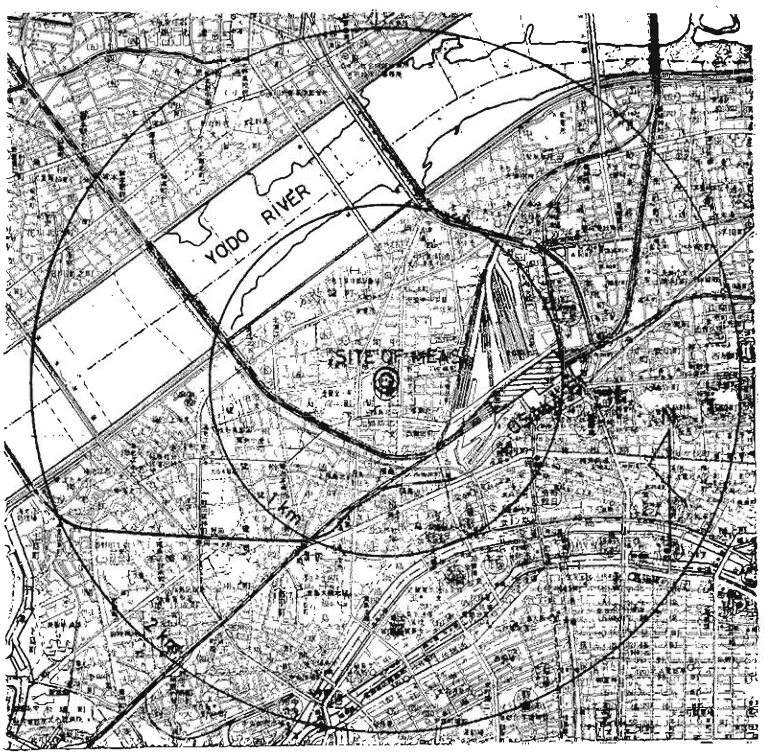


Fig. 3 Street map around the measurement site.

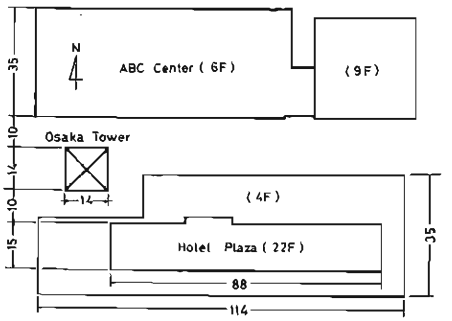


Fig. 4 Detailed plan of the measurement site. (unit in meters)

is 77m above the ground. The construction is of steel-reinforced concrete (1-4F) and steel (5-22F) with a curtain wall cladding. The exterior surface of the building is nearly flat and aerodynamically smooth.

4. Instrumentation

Osaka Tower (Fig. 5(a))

To observe the mean wind profile, four three-cup anemometers are mounted on the north-west corner (Photo. 3) of the tower 25m, 50m, 80m and 120m above the ground. The one of a height of 120m is equipped with a wind vane to observe the wind direction.

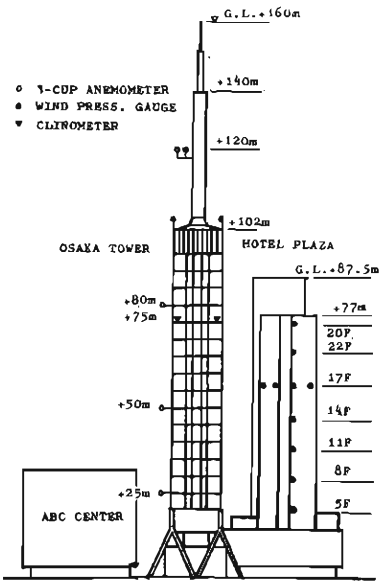


Fig. 5 Arrangement of instruments.
(a) West view

Velocity pressures are measured at 120m and 102m by Pitot-tube type pressure gauges with wind vanes. Other wind pressure gauges are ready for the measurement of the wind pressure on the walls of the look-out platform. The gradients of the horizontal plane at 75m of the tower are measured by differential transformer type clinometers.

All of the instruments are connected by cables to the look-out platform,

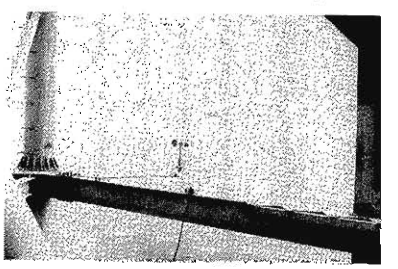


Photo. 3 Arrangement of a three-cup anemometer.

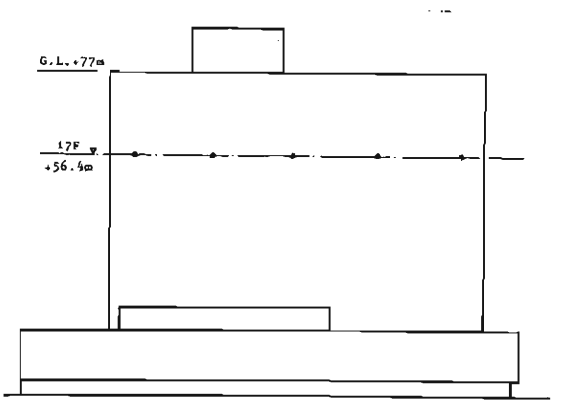


Fig. 5 Arrangement of instruments.
(b) South view

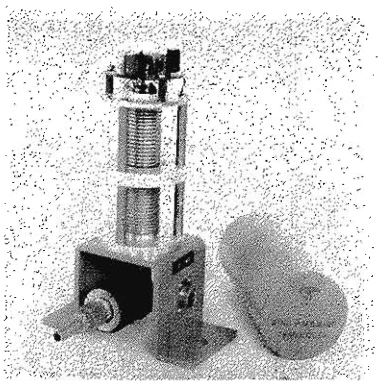


Photo. 4 Wind pressure gauge used in the measurement. (With cap removed)

where two five-channel and one two-channel scratch recorders are housed.

Plaza Hotel (Fig. 5(b))

Bellow type wind pressure gauges as shown in Photo. 4 were developed for the measurements. Fifteen gauges were arranged on the south and west faces of the building as shown in Fig. 5. They were set into the curtain wall and record the difference pressure between the static pressure outside the cladding which is required to be measured and the internal pressure, so the internal pressures of each gauge should be common and definite. As indicated by Newberry, it was very difficult to arrange such an internal pressure, so the wind pressure at each point was referred to the internal pressure of the nearest room.

The wind pressures are recorded by three five-channel scratch recorders housed in the basement.

For the measurements of the response, accelerometers which were arranged on the roof for earthquakes are available.

System of Measurements

Fig. 6 shows the whole system of the measurements. Wind speed measure-

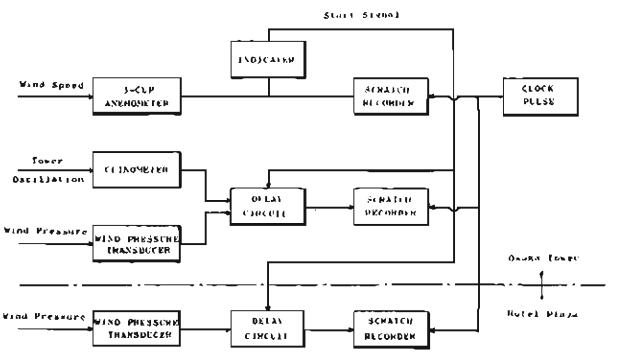


Fig. 6 Block diagram of the measurement.

ments by three-cup anemometer are routine. Other temporary ones start on a signal from the anemometer at 120m and recordings are conducted for arbitrary periods.

5. Oscillation of Osaka Tower in Wind

Some data for the strong wind of Typhoon 6909 were obtained on August 22, when this typhoon passed about 80km south of Osaka. A maximum wind speed of 18m/sec was observed at a height of 120m at Osaka Tower.

Wind pressures on the hotel building were not measured because the instrumentation had not been completed. Velocity pressures at 120m and the gradients of the horizontal plane at 75m were measured in the west wind. A part of the record is shown in Fig. 7.

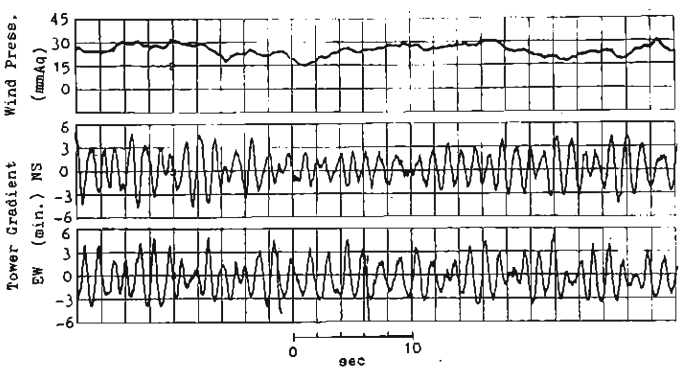


Fig. 7 Oscillogram of tower gradients and wind pressure.

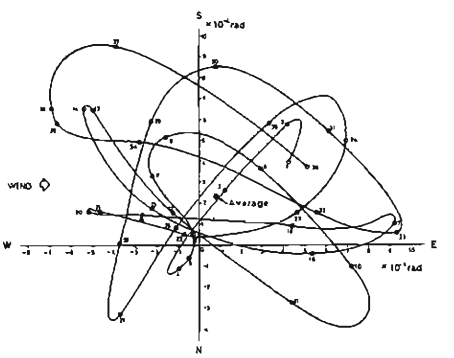
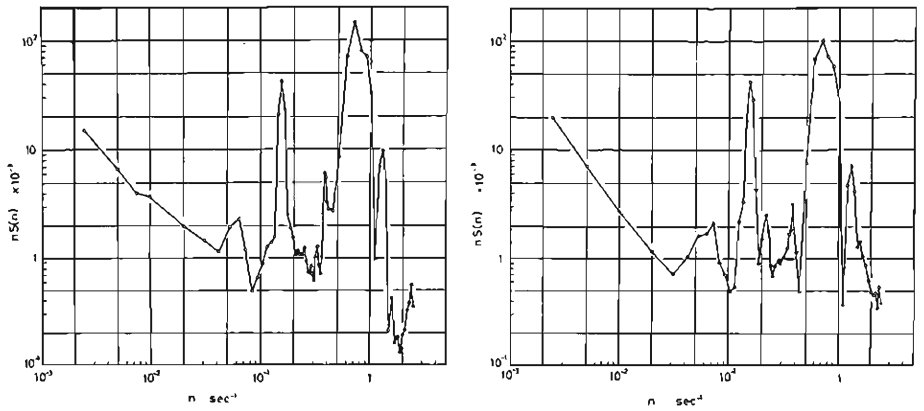


Fig. 8 Gradient motion of Osaka Tower in wind at a height of 75m above the ground. Gradients are numbered on a course of 0.2 seconds.

Gradients are plotted in Fig. 8 on a course of 0.2 seconds resulting the NS and EW components. The figure can be considered to be approximately a locus of the tower motion if the units of coordinates are changed appropriately. It will be noted that the tower motion is complicated and that the fluctuation is large compared to the average.



(a) NS component (b) EW component

Fig. 9 Power spectrum of tower gradients.

Power spectral density estimates of the tower gradients are calculated by Tukey's method and illustrated in Fig. 9 for the NS and EW components. Two peaks are found at frequencies of 0.8 and 0.15 1/sec. The peak at the frequency of 0.8 1/sec seems to correspond to the fundamental bending oscillation.

6. Conclusion

An experiment to measure the wind effects on a tall building and a TV tower in the city of Osaka is outlined. It is concerned with the wind structures over the city, the nature of wind loadings and the response of the building and tower. Tower oscillations were measured in a typhoon wind and some interesting phenomena were found.

Acknowledgements

The authors gratefully acknowledge the co-operation of the Asahi Broadcasting Co. Ltd., Japan Sheet Glass Co. Ltd. and Taisei Construction Co. Ltd. in allowing full scale measurements to be made, and the assistance of J. Hano and K. Sugimasa in carrying out the field tests.

References

1) Report of the Investigation of Damage Caused by the Muroto Typhoon. Journal of Architecture and Building Science, Vol. 48, No. 592, Dec. 1934, pp. 1365-1626. (in Japanese)
2) Rathbun, J.C.: Wind Forces on a Tall Building. Transactions, ASCE, No. 105, 1940, pp. 1-82.
3) Newberry, C.W.: The Measurement of Wind Pressures on Tall Buildings. Wind Effects on Buildings and Structures, Vol. 1, HMSO, 1965, pp. 113-149.
4) Wind Effects on Buildings and Structures. Vol. 1, University of Toronto Press, 1967.
5) Ishizaki, H. and Katsura, J.: On the Vibration of a Cylindrical Tower Structure Induced by Strong Winds. Bulletin of Disas. Prev. Res. Inst., Kyoto Univ., Vol. 19, Part 2, No. 155, Nov. 1969, pp. 19-23.